MASI: a novel Musculoskeletal model for the Analysis of Spinal Injuries

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Cervical spine trauma from sport collisions or vehicle accidents can have devastating consequences for individuals and a high societal cost. The precise mechanisms of such injuries are still unknown as investigation is hampered by the difficulty in experimentally replicating the conditions under which these injuries occur.

We report on the creation and validation of a generic musculoskeletal model for the analyses of cervical spine loading in healthy subjects. The novel improvements embedded in MASI consist of i) a scapula-clavicular joint (SCJ) that provides the coupled motion of scapula and clavicle with respect to humeral elevation, ii) the inclusion of body inertial parameters to permit dynamic analyses, and iii) an optimised scaling of neck muscles maximum isometric force. The verification and validation procedures consisted of i) SCJ kinematic validation, ii) a dynamic verification, and iii) a dynamic validation.

The 'Musculoskeletal model for the Analysis of Spinal Injuries' (MASI) was created in OpenSim 3.2 and Matlab 2013b software. MASI inherited the structure of the OpenSim head and neck model [1] which we embedded into a full body model (OpenSim '2354'). Experimental data of full body kinematics (Oqus, Qualisys), ground reaction forces (9287BA, Kistler), and neck muscles' EMG (Delsys Trigno, DelsysInc) of a healthy male subject (age: 64 years, height: 1.67 m, mass: 75 kg) were collected during neck flexion, extension, lateral bending and axial rotation movements. The SCJ kinematics throughout the humeral range of motion were within 2 standard deviations (SD) of previous *in vivo* and *in silico* studies. The passive neck joint moments were comparable with *in vitro* data (2 Nm) [2], and maximal net joint moments were comparable with healthy male subjects' neck strength (*Ext*: 50.8 Nm, *Flex*: 10.3 Nm, *Lat Bend*: 31.3 Nm, *Ax Rot*: 12.4 Nm). Finally, computed muscle control simulations driven by *in vivo* neck kinematic data successfully simulated neck muscles' activation (Fig. 1).

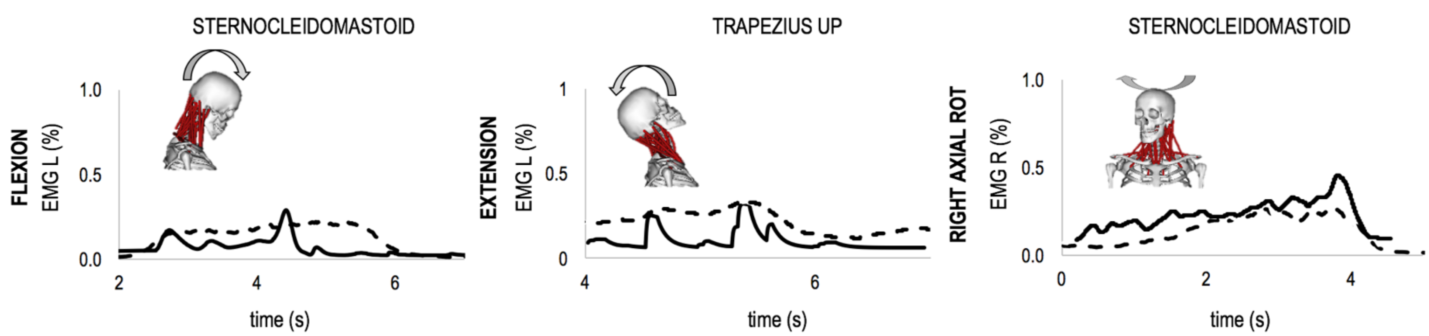

Figure 1: The simulated muscles (solid line) activation showed a similar pattern and activation level in comparison with the recorded EMGs (dashed line) across the neck movements.

The implementation of MASI for the analysis of dynamic loading experienced in both sporting and occupational activities will provide a greater understanding of the underlying mechanisms of cervical spine injuries.

References

1. Vasavada AN (1998) Influence of muscle morphometry and moment arms on the moment-generating capacity of human neck muscles. Spine 23:412-422.
2. Miura T (2002) A method to simulate in vivo cervical spine kinematics using in vitro compressive preload. Spine 27:43-48

Acknowledgments

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